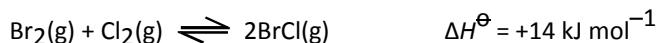


Topic 07 REVIEW – Equilibrium/Kinetics/Energetics

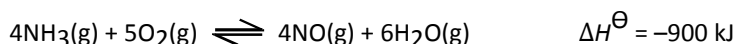
Name.....

1. What changes occur when the temperature is increased in the following reaction at equilibrium?



	Position of equilibrium	Value of equilibrium constant
A.	Shifts towards the reactants	Decreases
B.	Shifts towards the reactants	Increases
C.	Shifts towards the products	Decreases
D.	Shifts towards the products	Increases

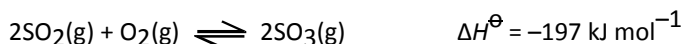
2. The equation for a reaction used in the manufacture of nitric acid is



Which changes occur when the temperature of the reaction is increased?

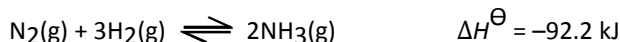
	Position of equilibrium	Value of K_c
A.	shifts to the left	increases
B.	shifts to the left	decreases
C.	shifts to the right	increases
D.	shifts to the right	decreases

3. The manufacture of sulfur trioxide can be represented by the equation below.



What happens when a catalyst is added to an equilibrium mixture from this reaction?

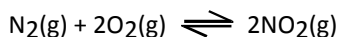
- A. The rate of the forward reaction increases and that of the reverse reaction decreases.
 B. The rates of both forward and reverse reactions increase.
 C. The value of ΔH^\ominus increases.
 D. The yield of sulfur trioxide increases.
4. The equation for the Haber process is:



Which conditions will favor the production of the greatest amount of ammonia at equilibrium?

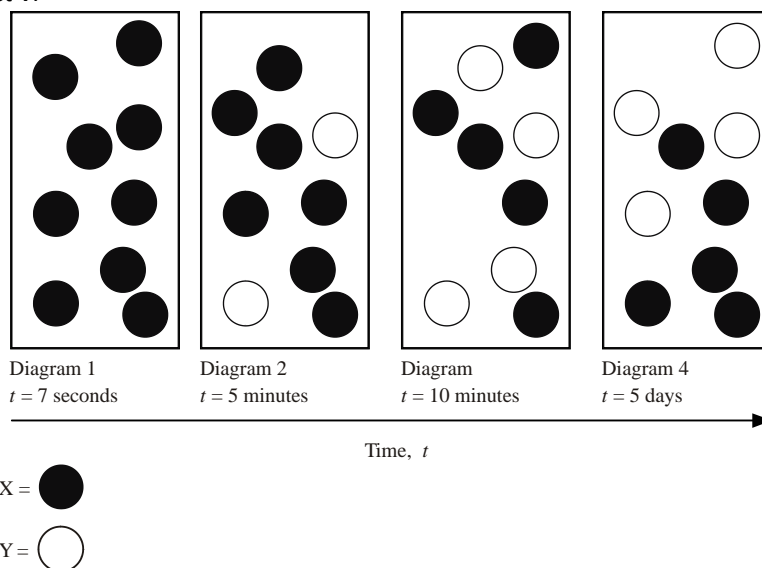
- A. High temperature and high pressure
 B. High temperature and low pressure
 C. Low temperature and high pressure
 D. Low temperature and low pressure
5. Which statement concerning a chemical reaction at equilibrium is **not** correct?
- A. The concentrations of reactants and products remain constant.
 B. Equilibrium can be approached from both directions.
 C. The rate of the forward reaction equals the rate of the reverse reaction.
 D. All reaction stops.

6. What is the equilibrium constant expression, K_c , for the reaction below?



- A. $K_c = \frac{[\text{NO}_2]}{[\text{N}_2][\text{O}_2]}$
 B. $K_c = \frac{2[\text{NO}_2]}{3[\text{N}_2][\text{O}_2]}$
 C. $K_c = \frac{[\text{NO}_2]^2}{[\text{N}_2][\text{O}_2]^2}$
 D. $K_c = \frac{[\text{NO}_2]^2}{[\text{N}_2] + [\text{O}_2]^2}$

7. The sequence of diagrams represents the system as time passes for a gas phase reaction in which reactant X is converted to product Y.



Which statement is correct?

- A. At $t = 5$ days the rate of the forward reaction is greater than the rate of the backward reaction.
- B. At $t = 7$ seconds the reaction has reached completion.
- C. At $t = 10$ minutes the system has reached a state of equilibrium.
- D. At $t = 5$ days the rate of the forward reaction is less than the rate of the backward reaction.
8. Sulfur dioxide and oxygen react to form sulfur trioxide according to the equilibrium.
- $$2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$$
- How is the amount of SO_3 and the value of the equilibrium constant for the reaction affected by an increase in pressure?
- A. The amount of SO_3 and the value of the equilibrium constant both increase.
- B. The amount of SO_3 and the value of the equilibrium constant both decrease.
- C. The amount of SO_3 increases but the value of the equilibrium constant decreases.
- D. The amount of SO_3 increases but the value of the equilibrium constant does not change.
9. A sealed container at room temperature is half full of water. The temperature of the container is increased and left for equilibrium to re-establish. Which statement is correct when the equilibrium is re-established at the higher temperature?
- A. The rate of vaporization is greater than the rate of condensation.
- B. The amount of water vapor is greater than the amount of liquid water.
- C. The amount of water vapor is greater than it is at the lower temperature.
- D. The rate of condensation is greater than the rate of vaporization.
10. The equation for a reversible reaction used in industry to convert methane to hydrogen is shown below.
- $$\text{CH}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + 3\text{H}_2(\text{g}) \quad \Delta H^\ominus = +210 \text{ kJ}$$
- Which statement is always correct about this reaction when equilibrium has been reached?
- A. The concentrations of methane and carbon monoxide are equal.
- B. The rate of the forward reaction is greater than the rate of the reverse reaction.
- C. The amount of hydrogen is three times the amount of methane.
- D. The value of ΔH^\ominus for the reverse reaction is -210 kJ .
11. Which statement is always true for a chemical reaction that has reached equilibrium?
- A. The yield of product(s) is greater than 50%.
- B. The rate of the forward reaction is greater than the rate of the reverse reaction.
- C. The amounts of reactants and products do not change.
- D. Both forward and reverse reactions have stopped.

12. In the Haber process for the synthesis of ammonia, what effects does the catalyst have?

	Rate of formation of NH ₃ (g)	Amount of NH ₃ (g) formed
A.	Increases	Increases
B.	Increases	Decreases
C.	Increases	No change
D.	No change	Increases

13. Which of the following equilibria would **not** be affected by pressure changes at constant temperature?

- A. $4\text{HCl(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2\text{H}_2\text{O(g)} + 2\text{Cl}_2\text{(g)}$
 B. $\text{CO(g)} + \text{H}_2\text{O(g)} \rightleftharpoons \text{H}_2\text{(g)} + \text{CO}_2\text{(g)}$
 C. $\text{C}_2\text{H}_4\text{(g)} + \text{H}_2\text{O(g)} \rightleftharpoons \text{C}_2\text{H}_5\text{OH(g)}$
 D. $\text{PF}_3\text{Cl}_2\text{(g)} \rightleftharpoons \text{PF}_3\text{(g)} + \text{Cl}_2\text{(g)}$

14. $2\text{SO}_2\text{(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2\text{SO}_3\text{(g)} \quad \Delta H^\ominus = -200 \text{ kJ}$

According to the above information, what temperature and pressure conditions produce the greatest amount of SO₃?

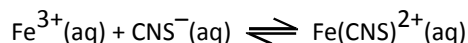
	Temperature	Pressure
A.	low	low
B.	low	high
C.	high	high
D.	high	low

15. What will happen if CO₂(g) is allowed to escape from the following reaction mixture at equilibrium?



- A. The pH will decrease.
 B. The pH will increase.
 C. The pH will remain constant.
 D. The pH will become zero.

16. Iron(III) ions react with thiocyanate ions as follows.



What are the units of the equilibrium constant, K_c , for the reaction?

- A. mol dm^{-3}
 B. $\text{mol}^2 \text{ dm}^{-6}$
 C. $\text{mol}^{-1} \text{ dm}^3$
 D. $\text{mol}^{-2} \text{ dm}^6$

17. Which statements are correct for a reaction at equilibrium?

- I. The forward and reverse reactions both continue.
 II. The rates of the forward and reverse reactions are equal.
 III. The concentrations of reactants and products are equal.

- A. I and II only
 B. I and III only
 C. II and III only
 D. I, II and III

18. Which statement(s) is/are true for a mixture of ice and water at equilibrium?

- I. The rates of melting and freezing are equal.
 II. The amounts of ice and water are equal.
 III. The same position of equilibrium can be reached by cooling water and heating ice.

- A. I only
 B. I and III only
 C. II only
 D. III only

19. The rate of a reversible reaction is altered by the addition of a heterogeneous catalyst. Which statement correctly describes the role of the catalyst?
- It alters the enthalpy change of the reaction.
 - It decreases the activation energy of the forward reaction.
 - It increases the activation energy of the reverse reaction.
 - It increases the rate of the forward reaction but decreases the rate of the reverse reaction.
20. A liquid and its vapor are at equilibrium inside a sealed container. Which change would alter the equilibrium vapor pressure of the liquid in the container?
- Adding more liquid
 - Adding more vapor
 - Decreasing the volume of the container
 - Decreasing the temperature
21. Consider the following reaction taking place at 375 °C in a 1.00 dm³ closed container.
- a) $\text{Cl}_2(\text{g}) + \text{SO}_2(\text{g}) \rightleftharpoons \text{SO}_2\text{Cl}_2(\text{g}) \quad \Delta H = -84.5 \text{ kJ mol}^{-1}$
- i) Deduce the equilibrium constant expression, K_c , for the reaction. [1]
- ii) If the temperature of the reaction is changed to 300 °C, predict, stating a reason in each case, whether the equilibrium concentration of SO_2Cl_2 and the value of K_c will increase or decrease. [3]
- iii) If the volume of the container is changed to 1.50 dm³, predict, stating a reason in each case, how this will affect the equilibrium concentration of SO_2Cl_2 and the value of K_c . [3]
- iv) Suggest, stating a reason, how the addition of a catalyst at constant pressure and temperature will affect the equilibrium concentration of SO_2Cl_2 . [2]
- b) Graphing is an important method in the study of the rates of chemical reaction. Sketch a graph to show how the reactant concentration changes with time in a typical chemical reaction taking place in solution. Show how the rate of the reaction at a particular time can be determined. [4]
- c) A solution of hydrogen peroxide, H_2O_2 , is added to a solution of sodium iodide, NaI , acidified with hydrochloric acid, HCl . The yellow color of the iodine, I_2 , can be used to determine the rate of reaction.
- $\text{H}_2\text{O}_2(\text{aq}) + 2\text{NaI}(\text{aq}) + 2\text{HCl}(\text{aq}) \rightarrow 2\text{NaCl}(\text{aq}) + \text{I}_2(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$
- The experiment is repeated with some changes to the reaction conditions. For each of the changes that follow, predict, stating a reason, its effect on the rate of reaction.
- i) The concentration of H_2O_2 is increased at constant temperature. [2]

- ii) The solution of NaI is prepared from a fine powder instead of large crystals.

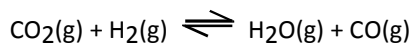
[2]

- d) Explain why the rate of a reaction increases when the temperature of the system increases.

[3]

[Total 20 marks]

22. (a) The following equilibrium is established at 1700°C.



If only carbon dioxide gas and hydrogen gas are present initially, sketch on a graph a line representing rate against time for (i) the forward reaction **and** (ii) the reverse reaction until shortly after equilibrium is established. Explain the shape of each line.

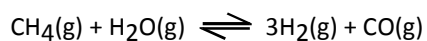
(7)

- (b) K_c for the equilibrium reaction is determined at two different temperatures. At 850°C, $K_c = 1.1$ whereas at 1700°C, $K_c = 4.9$. On the basis of these K_c values explain whether the reaction is exothermic or endothermic.

(3)

(Total 10 marks)

23. The equation for a reaction used in industry is

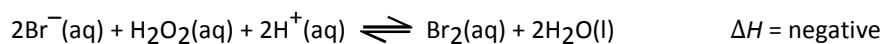


$$\Delta H^\ominus = +210 \text{ kJ}$$

Deduce the equilibrium constant expression, K_c , for this reaction.

(Total 1 mark)

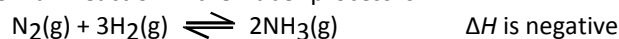
24. Consider the following reaction where colorless bromide ions react with colorless hydrogen peroxide to form a red-brown bromine solution.



State and explain the color change when hydrochloric acid is added to the reaction solution at equilibrium.

(Total 3 marks)

25. The equation for the main reaction in the Haber process is:



(iii) In practice, typical conditions used in the Haber process involve a temperature of 500°C and a pressure of 200 atm. Explain how these are different than what Le Chatelier predicts will produce the highest yield, and why these conditions are used instead:

(Total 6 marks)